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(54) **SELF-FILLING SOIL PROCESSING CHAMBER WITH DYNAMIC EXTRACTANT VOLUME**

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G01N 19/10 (2006.01)
G01N 15/06 (2006.01)

(52) **U.S. Cl.**
CPC ***G01N 19/10*** (2013.01); ***G01N 15/06*** (2013.01)

(58) **Field of Classification Search**
CPC G01N 15/06; G01N 19/10
USPC 73/73, 76
See application file for complete search history.

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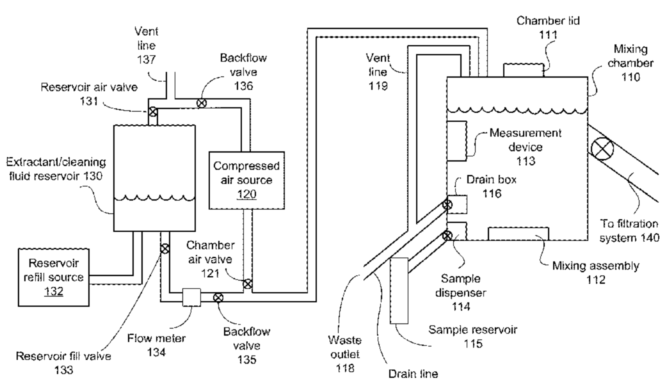
(57) **ABSTRACT**

A soil analysis device is configured to create a soil sample solution. The device includes a reservoir configured to store an extractant, a mixing chamber coupled to the reservoir and configured to receive extractant from the reservoir and to receive a raw soil sample, and a control system. The control system is configured to determine an amount of extractant needed to produce, from the raw soil sample, a soil sample solution with a particular soil-to-extractant ratio and configured to cause the determined amount of extractant to be transferred from the reservoir to the mixing chamber.

16 Claims, 9 Drawing Sheets



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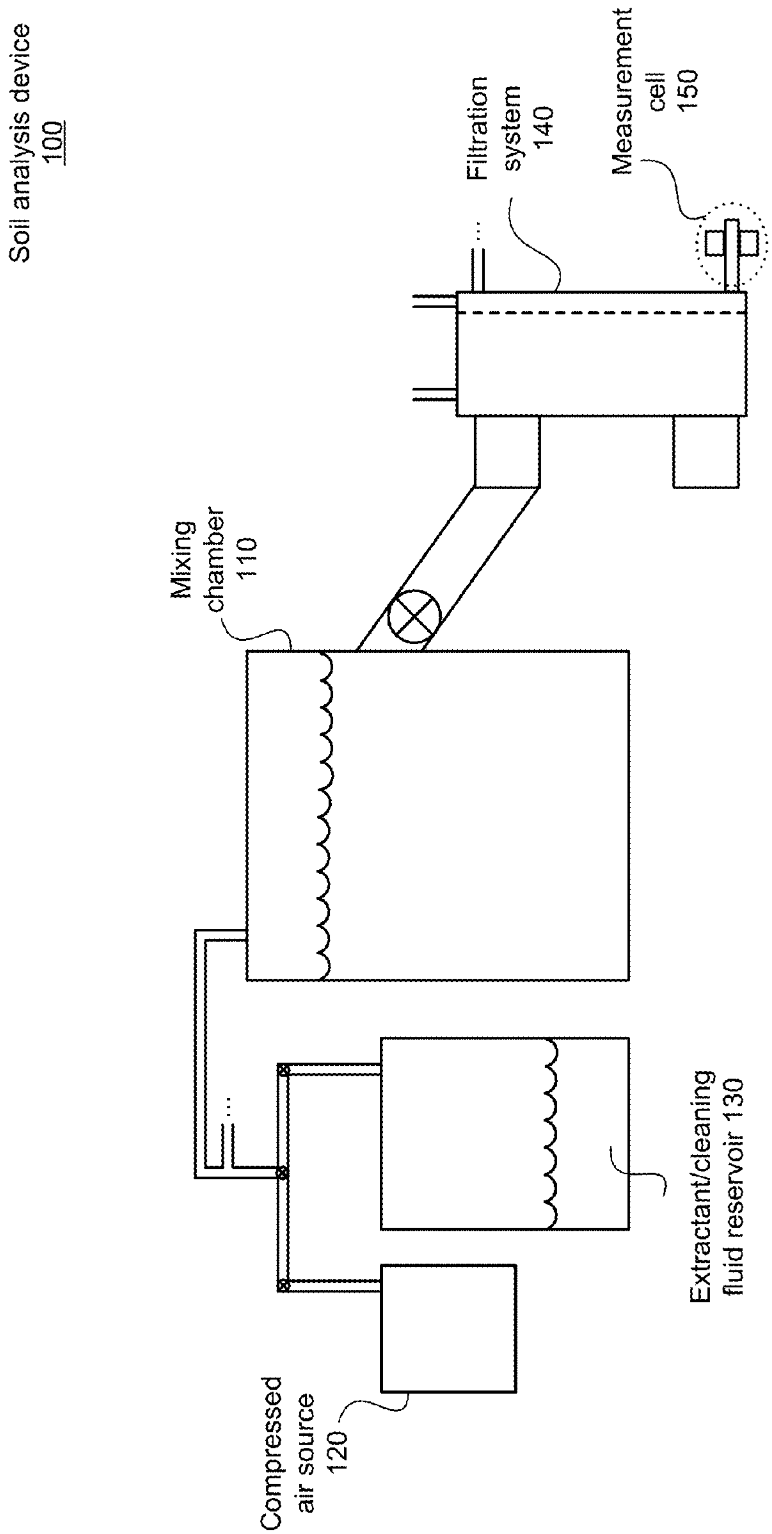

Soil analysis device
100
Mixing chamber
110
Filtration system
140
Measurement cell
150
Compressed air source
120
Extractant/cleaning fluid reservoir 130

FIG. 1

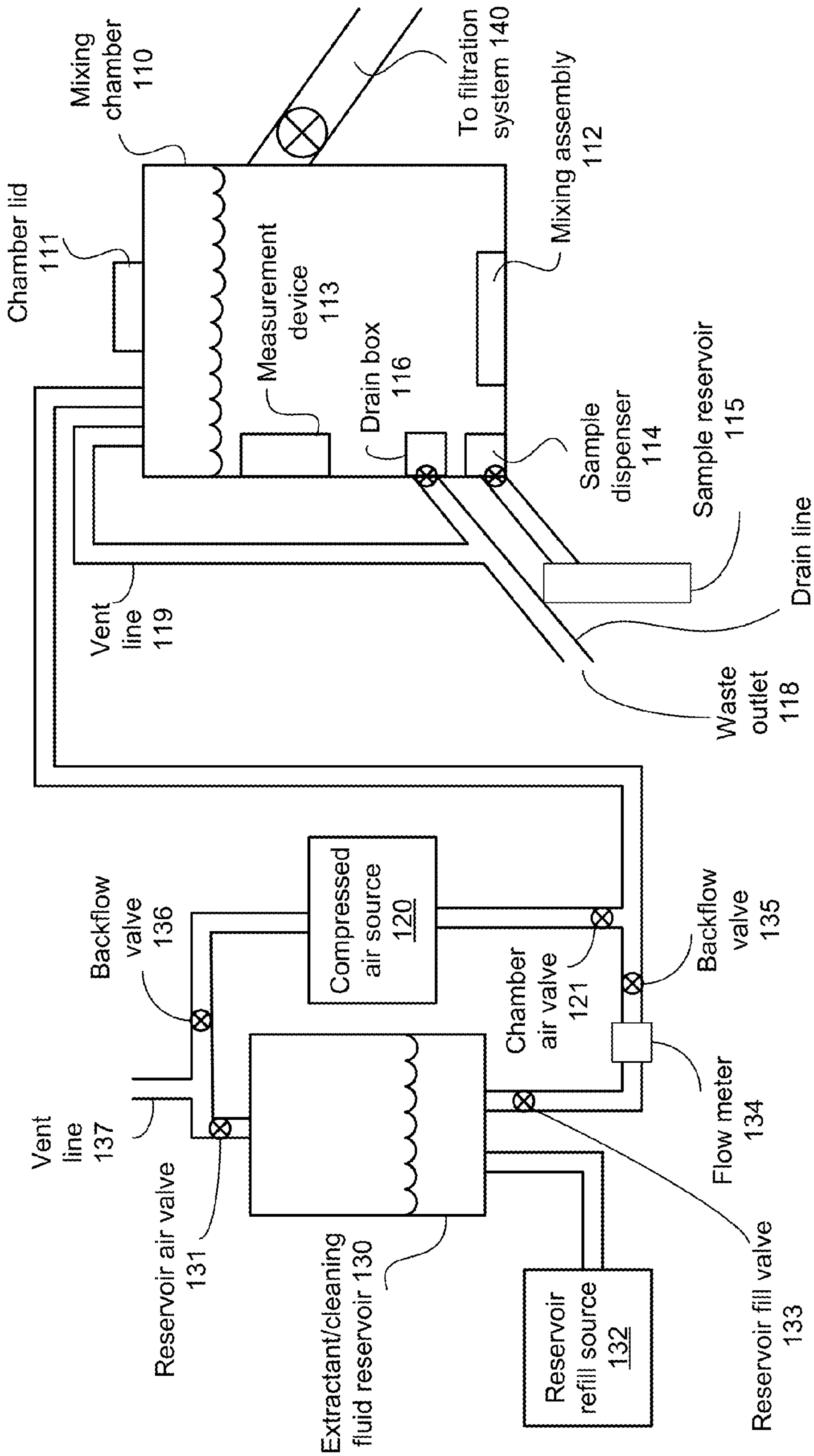

Mixing chamber 110
To filtration system 140
Chamber lid 111
Mixing assembly 112
Measurement device 113
Drain box 116
Sample dispenser 114
Sample reservoir 115
Drain line 117
Vent line 119
Waste outlet 118
Compressed air source 120
Backflow valve 136
Backflow valve 135
Chamber air valve 121
Flow meter 134
Vent line 137
Reservoir air valve 131
Extractant/cleaning fluid reservoir 130
Reservoir refill source 132
Reservoir fill valve 133

FIG. 2

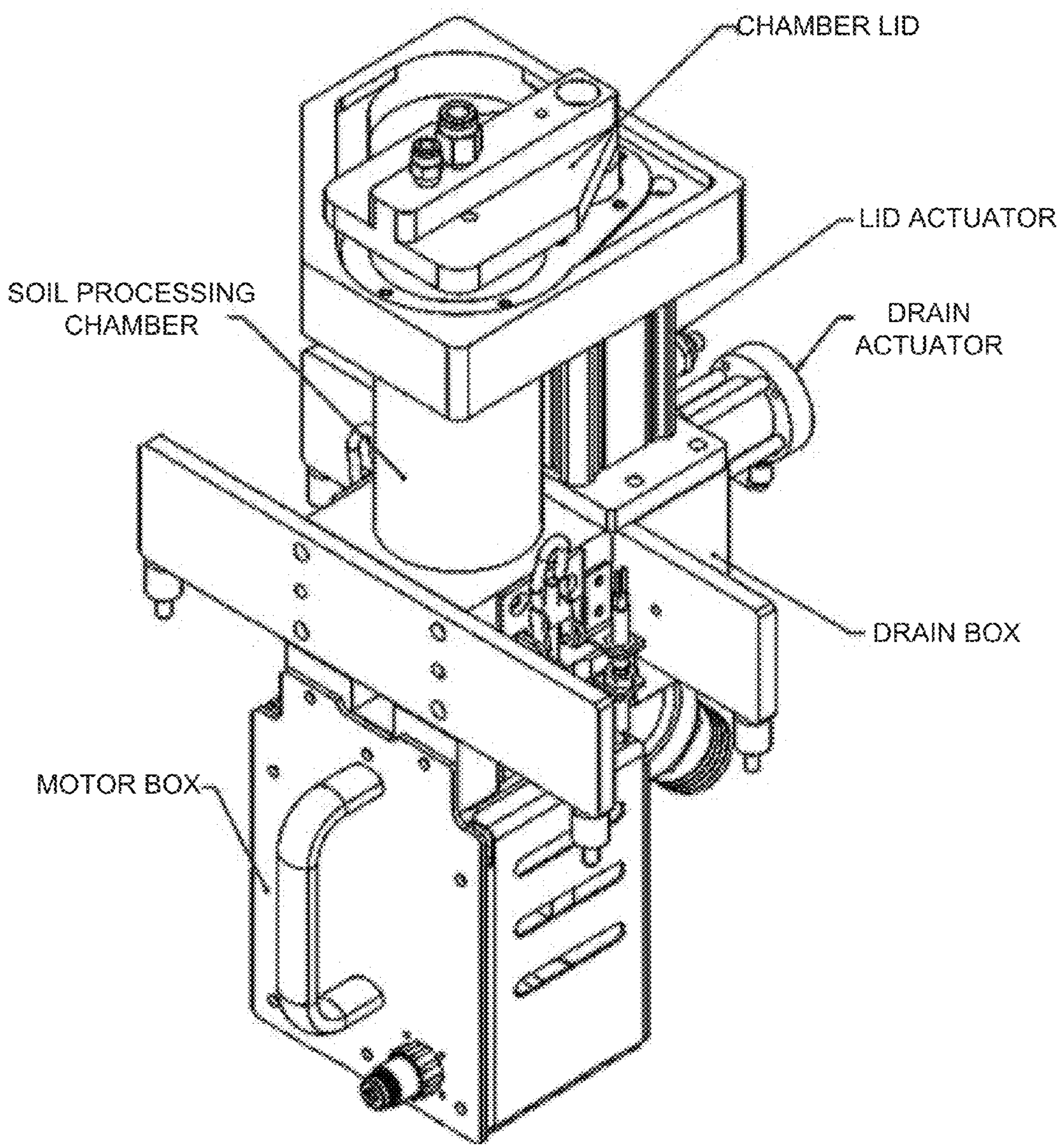
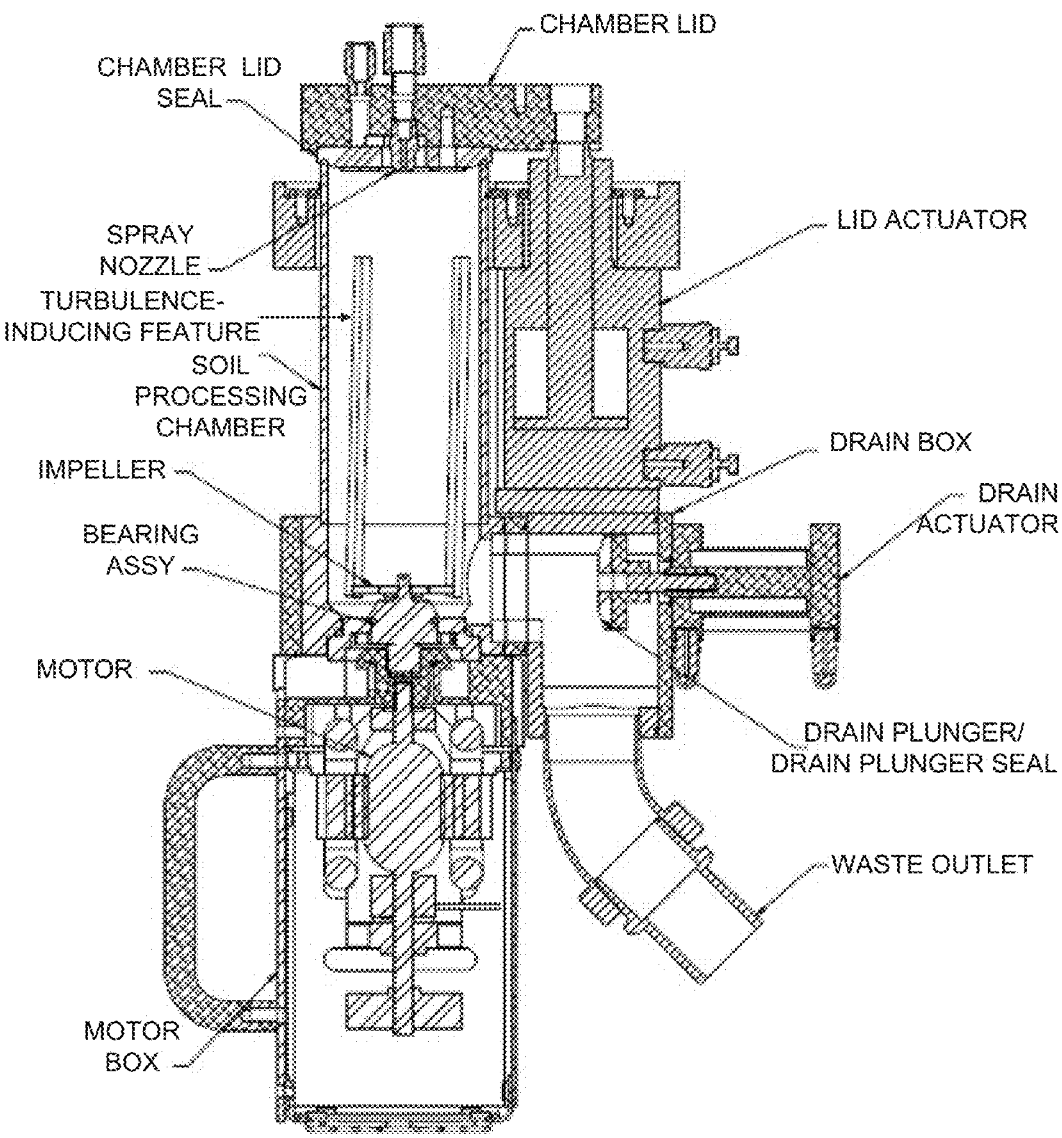

CHAMBER LID
LID ACTUATOR
SOIL PROCESSING CHAMBER
DRAIN ACTUATOR
DRAIN BOX
MOTOR BOX

FIG. 3



CHAMBER LID
CHAMBER LID SEAL
SPRAY NOZZLE
TURBULENCE-INDUCING FEATURE
SOIL PROCESSING CHAMBER
IMPELLER
BEARING ASSY
MOTOR
MOTOR BOX
LID ACTUATOR
DRAIN BOX
DRAIN ACTUATOR
DRAIN PLUNGER/ DRAIN PLUNGER SEAL
WASTE OUTLET

FIG. 4

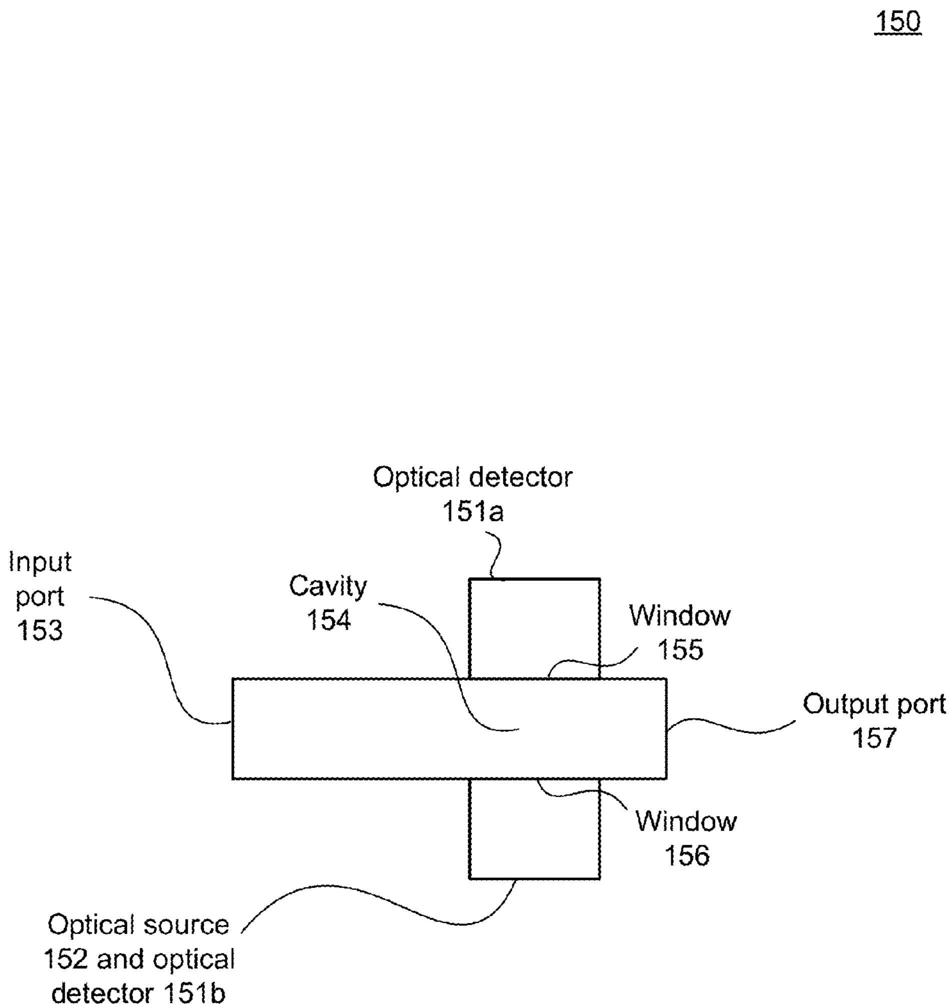

150
Optical detector
151a
Input
port
153
Cavity
154
Window
155
Output port
157
Window
156
Optical source
152 and optical
detector 151b

FIG. 5

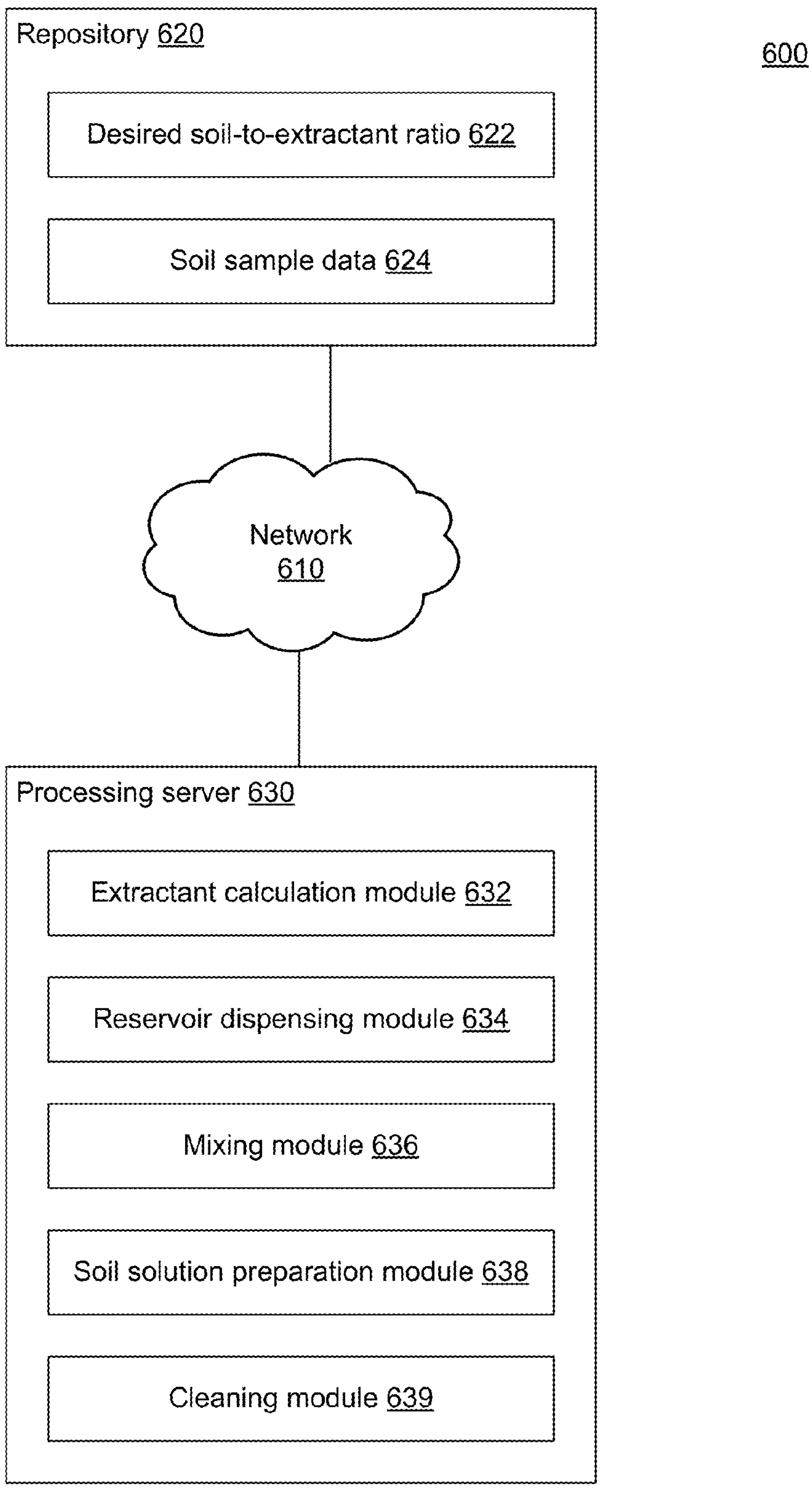

Repository 620
Desired soil-to-extractant ratio 622
Soil sample data 624
600
Network 610
Processing server 630
Extractant calculation module 632
Reservoir dispensing module 634
Mixing module 636
Soil solution preparation module 638
Cleaning module 639

FIG. 6

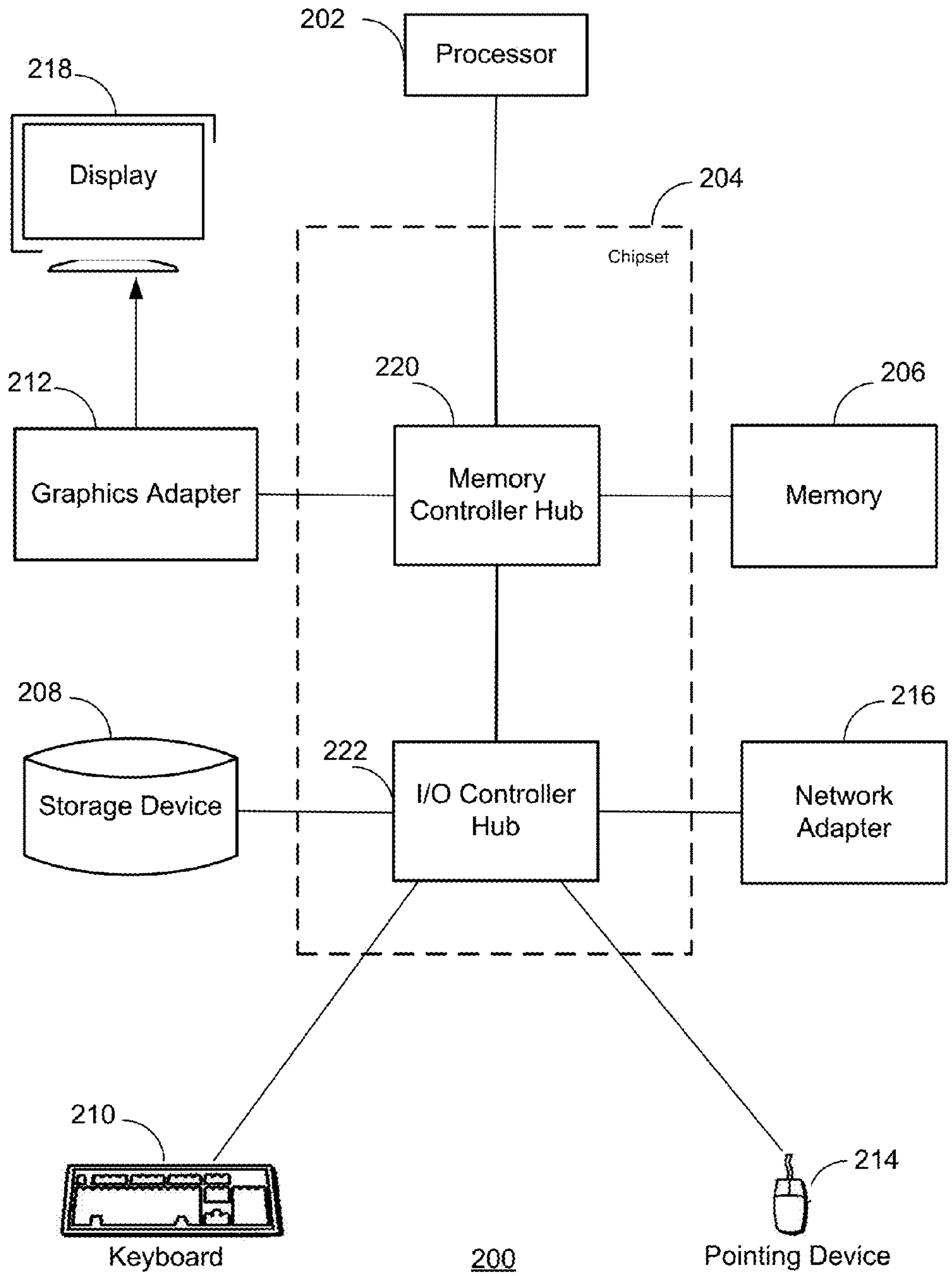

202
Processor
218
Display
204
Chipset
212
220
206
Graphics Adapter
Memory Controller Hub
Memory
208
216
222
Storage Device
I/O Controller Hub
Network Adapter
210
214
Keyboard
200
Pointing Device

FIG. 7

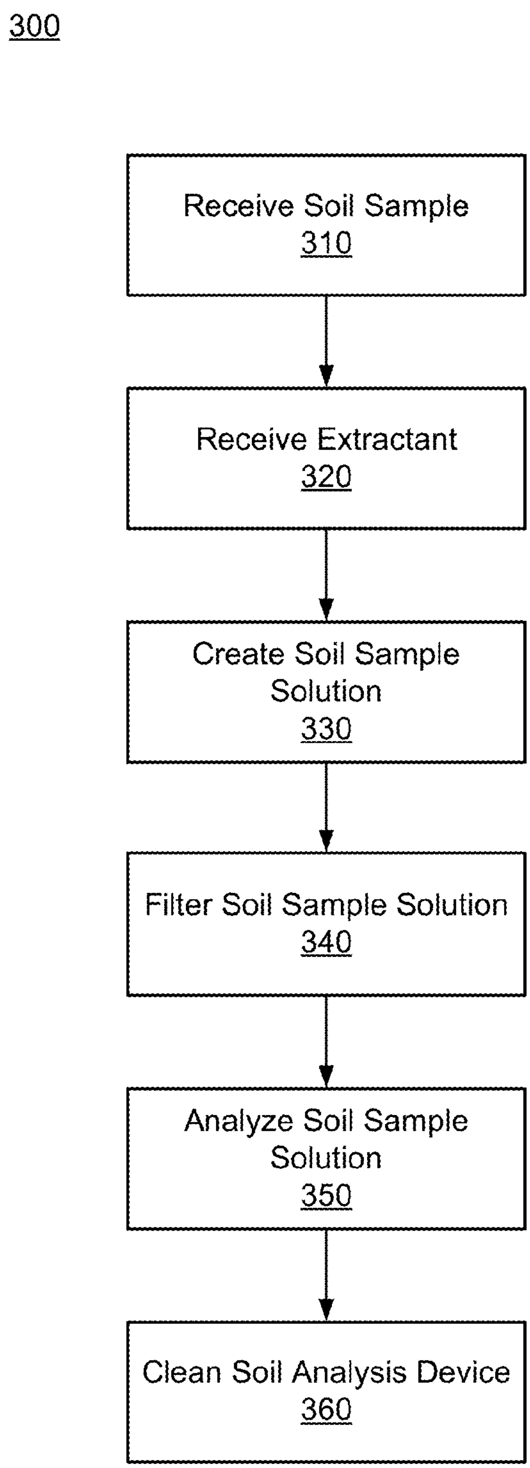

300
Receive Soil Sample
310
Receive Extractant
320
Create Soil Sample Solution
330
Filter Soil Sample Solution
340
Analyze Soil Sample Solution
350
Clean Soil Analysis Device
360

FIG. 8

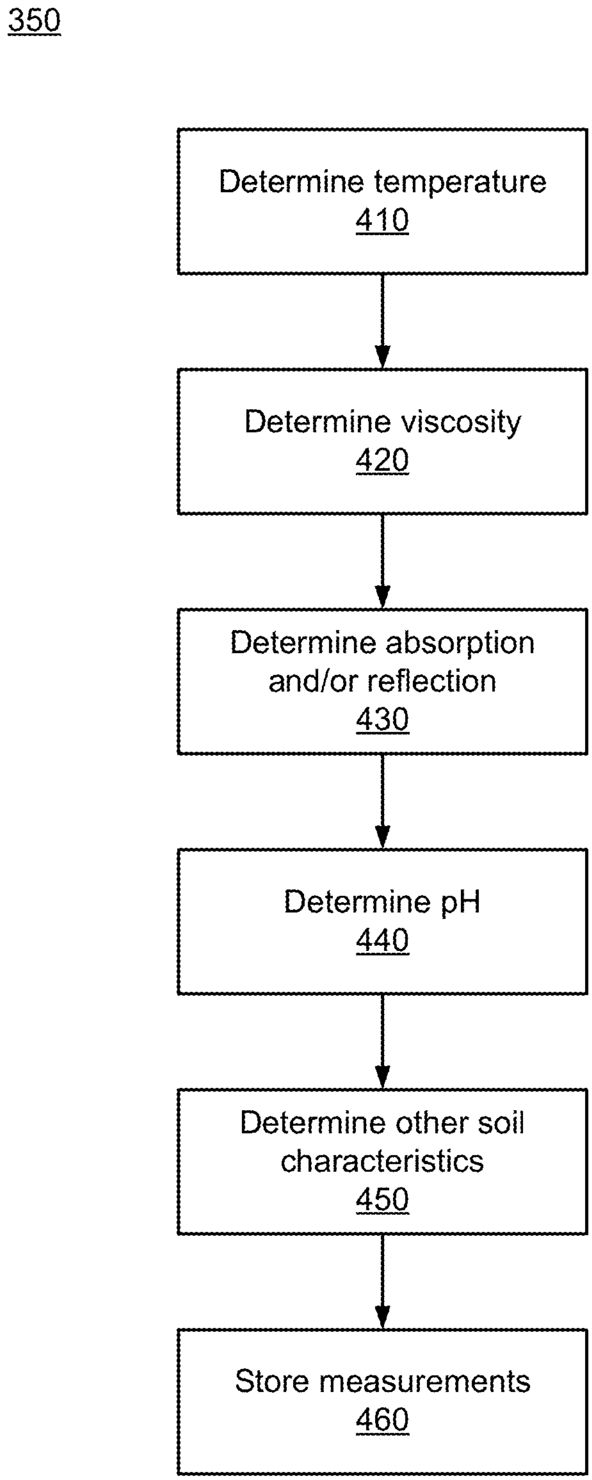

350
Determine temperature 410
Determine viscosity 420
Determine absorption and/or reflection 430
Determine pH 440
Determine other soil characteristics 450
Store measurements 460

FIG. 9

SELF-FILLING SOIL PROCESSING CHAMBER WITH DYNAMIC EXTRACTANT VOLUME

RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 61/697,718, filed Sep. 6, 2012, which is incorporated by reference herein in its entirety.

BACKGROUND

1. Field of Art

The invention generally relates to the field of soil measurement and testing and in particular to automated measurement and testing of soil properties.

2. Background Information

Traditionally, a raw soil sample is processed by first completely drying it and then thoroughly grinding it so that it has a uniform moisture content and can be easily subsampled. This enables a soil sample to be efficiently processed at a low cost. However, the process of drying and grinding a soil sample can drastically change the resulting soil nutrient measurements. In particular, potassium levels can vary substantially with soil type and extent of drying performed before processing the sample.

More agronomically representative results can be achieved by performing field-moist analysis, instead of using a drying and grinding process. In one embodiment, a soil sample solution is prepared by combining a raw soil sample and an extractant (e.g., deionized water). Field-moist analysis is then performed on the solution. In order to increase the accuracy of the analysis, it is helpful to clean the equipment between soil samples.

SUMMARY

The above and other problems are addressed by a soil analysis device. One embodiment of the device is configured to create a soil sample solution and includes a reservoir configured to store an extractant, a mixing chamber coupled to the reservoir and configured to receive extractant from the reservoir and to receive a raw soil sample, and a control system. The control system is configured to determine an amount of extractant needed to produce, from the raw soil sample, a soil sample solution with a particular soil-to-extractant ratio and configured to cause the determined amount of extractant to be transferred from the reservoir to the mixing chamber.

Another embodiment of the device includes a reservoir configured to store a cleaning fluid, a mixing chamber coupled to the reservoir, and a control system. The mixing chamber is configured to produce a soil sample solution, output the produced soil sample solution, receive cleaning fluid from the reservoir, move the received cleaning fluid within the mixing chamber, and output the received cleaning fluid. The control system is configured to cause the cleaning fluid to be transferred from the reservoir to the mixing chamber, cause the mixing chamber to move the transferred cleaning fluid within the mixing chamber to rinse the mixing chamber, and cause the mixing chamber to output the transferred cleaning fluid.

BRIEF DESCRIPTION OF DRAWINGS

Figure (FIG. **1** is a block diagram of a soil analysis device configured to create a soil sample solution, according to one embodiment.

FIG. **2** is a block diagram providing more detail regarding the mixing chamber, compressed air source, and reservoir shown in FIG. **1**, according to one embodiment.

FIG. **3** is a three-dimensional external view of the mixing chamber shown in FIG. **1**, according to one embodiment.

FIG. **4** is a cross-sectional view of the mixing chamber shown in FIG. **1**, according to one embodiment.

FIG. **5** is a block diagram of a measurement cell for analyzing a soil sample solution, according to one embodiment.

FIG. **6** is a high-level block diagram illustrating a system for controlling a soil analysis device configured to create a soil sample solution, according to one embodiment.

FIG. **7** is a high-level block diagram illustrating an example of a computer for use as a repository and/or a processing server, according to one embodiment.

FIG. **8** is a flow chart of a method for analyzing a soil sample solution, according to one embodiment.

FIG. **9** is a flow chart of a method for capturing multiple types of measurements to determine soil composition, according to one embodiment.

DETAILED DESCRIPTION

The Figures (FIGS.) and the following description describe certain embodiments by way of illustration only. One skilled in the art will readily recognize from the following description that alternative embodiments of the structures and methods illustrated herein may be employed without departing from the principles described herein. Reference will now be made to several embodiments, examples of which are illustrated in the accompanying figures. It is noted that wherever practicable similar or like reference numbers may be used in the figures and may indicate similar or like functionality.

Structure of Soil Analysis Device

FIG. **1** is a block diagram of one embodiment of a soil analysis device **100**. In one embodiment, the soil analysis device **100** includes a mixing chamber **110**, a compressed air source **120**, one or more reservoirs that contain extractant and/or cleaning fluid **130**, a filtration system **140** and a measurement cell **150**. In an alternative embodiment, the measurement cell **150** is absent and the device **100** comprises an output port (not shown) for apportioning out a volume of filtered solution for collection and testing external to the device **100**. The soil analysis device **100** also includes a control system (not shown) for controlling the operation of the soil analysis device. The control system is described below with reference to FIGS. **6** and **7**.

Generally, the mixing chamber **110** is configured to receive a raw soil sample and an extractant (e.g., deionized water), mix them together, and provide the mixed solution (or "slurry") to the filtration system **140**. The filtration system **140** filters the slurry and provides the filtered output to the measurement cell **150** for testing, or the filtration system dispenses the raw slurry through an output port (without filtering it) for further processing and analysis. In one embodiment, the control system causes extractant to be moved from a reservoir **130** to the mixing chamber **110**. In another embodiment, the control system causes the soil analysis device **100** to use air from the compressed air source **120** and a cleaning fluid (e.g., deionized water) from a reservoir **130** to automate self-cleaning of the mixing chamber **110**, filtration system **140**, and/or the measurement cell **150** or output port. Cleaning the various components of the device **100** ensures that the analysis of a later-received soil sample is not tainted by a previously-received soil sample.

FIG. **2** is a block diagram providing more detail regarding the mixing chamber **110**, compressed air source **120**, and reservoir **130** shown in FIG. **1**, according to one embodiment. Like FIG. **1**, FIG. **2** shows a mixing chamber **110**, a compressed air source **120**, and a reservoir that contains extractant and/or cleaning fluid **130**. The mixing chamber **110** is coupled to the reservoir **130** using one or more pipes and/or tubes. The mixing chamber **110** is also coupled to the compressed air source **120** using one or more pipes and/or tubes. The reservoir **130** is also coupled to the compressed air source **120** using one or more pipes and/or tubes.

Unlike FIG. **1**, FIG. **2** also shows additional elements related to the mixing chamber **110**, the compressed air source **120**, and the reservoir **130**. In the embodiment illustrated in FIG. **2**, the mixing chamber **110** includes a chamber lid **111**, a mixing assembly **112**, a measurement device **113**, a sample dispenser **114**, and a drain box **116**. The mixing chamber **110** includes an entry port (not shown) that can be used to add material to and/or remove material from the mixing chamber. For example, the entry port can be used to add a raw soil sample to the mixing chamber. Material can be added to or removed from the mixing chamber manually or through an automated mechanism. The chamber lid **111** seals this entry port and can be moved if desired (e.g., to gain access to the entry port). In one embodiment, the chamber lid **111** includes an actuator that can be controlled to move the lid. For purposes of illustration, FIG. **2** depicts an embodiment where the chamber lid **111** (and, therefore, the entry port) is located at the top of the mixing chamber **110**. However, the chamber lid **111** (and, therefore, the entry port) can be located elsewhere (e.g., on the side of the mixing chamber **110**).

The mixing assembly **112** mixes the contents of the mixing chamber **110** (e.g., a raw soil sample and extractant) to produce a homogenized soil sample solution. The mixing assembly **112** can use any suitable mixing method. In one embodiment, the mixing assembly **112** includes one or more blades attached to a motor. The motion of the motor causes the blades to spin, thereby mixing the contents of the mixing chamber **110**. The operation of the motor and the movement of the blades produce a soil sample solution by agitating the contents of the mixing chamber **110**. In one embodiment, the motor and blades agitate the contents for a predetermined length of time or until receiving a control signal from an external controller. For purposes of illustration, FIG. **2** depicts an embodiment where the mixing assembly **112** is located at the bottom of the mixing chamber **110**. However, the mixing assembly **112** can be configured to operate anywhere within the mixing chamber **110**.

In one embodiment, the motor is connected to a mixing shaft to facilitate mixing the contents of the mixing chamber **110**. In one embodiment, the mixing shaft enters the mixing chamber **110** from an entry port on the top of the mixing chamber **110**. In other embodiments, however, the mixing shaft enters the mixing chamber **110** from an opening on the bottom or side of the mixing chamber **110**.

In other embodiments, the mixing assembly **112** can use one or more of sonication, heating or chemical addition, or any other method of mixing or combination of methods of mixing to combine the contents of the mixing chamber **110**. In one embodiment, ultrasonic waves from a source are applied to the contents to reduce the amount of particulates by breaking up soil. In another embodiment, a centrifugal force is applied to the contents to separate particulates from fluid material. The separated particulates can then be removed from the mixing chamber **110**.

In one embodiment, the mixing assembly **112** includes a turbulence-inducing feature that facilitates the mixing of the contents of the mixing chamber **110**. In one embodiment, the turbulence-inducing feature is a flat bar introducing into a cylindrical mixing chamber **110**. The operation of the motor with attached blades or mixing shaft can create an approximately circular flow that circulates the contents of the mixing chamber **110** without effectively mixing the contents. The addition of a flat bar interrupts the regularized motion (or flow) of the contents of the mixing chamber **110** while the motor is in operation, creating a more turbulent flow that improves the mixing of the contents of the mixing chamber **110**. Thus, the addition of the turbulence-inducing feature decreases the amount of time needed to mix the contents of the mixing chamber **110** to create the soil sample solution.

The measurement device **113** is discussed below.

In the embodiment illustrated in FIG. **2**, the mixing chamber **110** includes three outlet ports, which enable removal of the contents of the mixing chamber **110**. In one embodiment, an outlet port is an opening having a valve and/or a movable cover, so that opening the valve and/or moving the cover enables drainage of the contents of the mixing chamber **110**. One port leads to the filtration system **140**, one port (the sample dispenser **114**) leads to a sample reservoir **115**, and one port (the drain box **116**) leads to a waste outlet **118**. The sample dispenser **114** drains the contents of the mixing chamber **110** into a sample reservoir **115**. The contents of the sample reservoir **115** can then be removed and either stored for future use or further processed for measurement by a separate system such as an inductively-coupled-plasma atomic-emission-spectoscopy (ICP-AES) tool, flow-injection-analyzer (FIA) tool, or ion selective electrode (ISE) tool. The drain box **116** drains the contents of the mixing chamber **110** through a drain line **117** to a waste outlet **118** for disposal. The mixing chamber **110** also includes a vent line **119**, which enables the contents of the mixing chamber **110** to overflow into the drain line **117**.

The reservoir that contains extractant and/or cleaning fluid **130** is configured to provide that extractant and/or cleaning fluid to the mixing chamber **110** through one or more pipes and/or tubes. In one embodiment, the mixing chamber **110** receives a raw soil sample through its entry port but receives extractant and/or cleaning fluid from the reservoir **130** through the one or more pipes and/or tubes.

The reservoir **130** stores extractant and/or cleaning fluid in a pressurized manner using compressed air source **120**, reservoir air valve **131**, and reservoir fill valve **133**. The reservoir air valve **131** is located between the compressed air source **120** and the reservoir **130** within a pipe or tube coupling the compressed air source **120** to the reservoir **130**. The reservoir fill valve **133** is located between the reservoir **130** and the mixing chamber **110** within a pipe or tube coupling the reservoir **130** to the mixing chamber **110**.

In one embodiment, extractant and/or cleaning fluid is moved from the reservoir **130** to the mixing chamber **110** as follows: The reservoir air valve **131** and the reservoir fill valve **133** open. The chamber air valve **121** closes. The compressed air source **120** pushes air through the backflow valve **136** and the reservoir air valve **131** into the pressurized reservoir **130**. The backflow valve **136** prevents fluid from flowing from the pressurized reservoir **130** to the compressed air source **120**. The vent line **137** allows air to flow out of the reservoir **130** during filling. The air entering the pressurized reservoir **130** causes extractant and/or cleaning fluid to exit the reservoir **130** through the reservoir fill valve **133**. The exiting extractant and/or cleaning fluid flows through a flow meter **134**, which measures the flow of the extractant and/or cleaning fluid. The amount of the measured flow is used to determine how much extractant and/or cleaning fluid is being added to the mixing chamber **110** (further explained below). After flowing through the flow meter **134**, the extractant and/or cleaning fluid flows through the backflow valve **135** and eventually enters the mixing chamber **110**. The backflow valve **135** prevents fluid from flowing from the mixing chamber **110** to the reservoir **130**. In one embodiment, a spray nozzle (not shown) is used to add the extractant and/or cleaning fluid to the mixing chamber **110**.

The reservoir **130** acts as a separate container for collecting and storing extractants, so that when a soil measurement is to be performed, extractant is ready for use and can be transferred to the mixing chamber **110**. For example, the reservoir **130** can store a large volume of extractant (e.g., one liter or more) and can transfer this extractant to the mixing chamber **110** in a short amount of time (e.g., a few seconds). This is particularly useful if it is time-consuming to generate large amounts of the extractant. For example, the process for generating large volumes of deionized water (one example of an extractant) requires time on the order of minutes per liter.

In one embodiment, the reservoir **130** is refilled while a soil sample measurement is taking place, thereby decreasing the amount of time required to prepare the soil analysis device **100** for the next soil sample to be analyzed. In one embodiment, the reservoir **130** is coupled to a reservoir refill source **132** by one or more pipes and/or tubes. The reservoir **130** is refilled by transferring extractant and/or cleaning fluid from the reservoir refill source **132** to the reservoir **130** through the one or more pipes and/or tubes.

It is sometimes desirable to add a particular amount of extractant and/or cleaning fluid to the mixing chamber **110**. For example, a particular amount of extractant is needed in order to prepare a soil sample solution with a particular soil-to-extractant ratio. In this situation, it is necessary to determine how much extractant and/or cleaning fluid has been added to the mixing chamber **110** so far and whether additional extractant and/or cleaning fluid is needed. Recall that the flow meter **134** measures the flow of the extractant and/or cleaning fluid out of the reservoir **130** on its way to the mixing chamber **130**. However, the amount of the measured flow is not necessarily the only extractant and/or cleaning fluid that is being added to the mixing chamber. Additional extractant and/or cleaning fluid might already be present in the pipes and/or tubes between the flow meter **134** and the mixing chamber **110**. This additional amount (of unknown size) would also be added to the mixing chamber, making it difficult to determine the exact amount of extractant and/or cleaning fluid that is being added.

To address this problem, the compressed air source **120** can be used to clear out pipes and/or tubes (leading to the mixing chamber **110**) of their contents. Once the relevant pipes and/or tubes have been cleared out, the flow meter **134** can be used to indicate exactly how much extractant and/or cleaning fluid is being added to the mixing chamber. In one embodiment, these pipes and/or tubes are cleared of their contents as follows: The chamber air valve **121** opens. The compressed air source **120** pushes air through the chamber air valve **121**. After flowing through the chamber air valve **121**, the air flows through the relevant pipes and/or tubes, clearing them of their contents. (The backflow valve **135** prevents the air from flowing to the reservoir **130**.) Eventually, the air (and the former contents of the pipes and/or tubes) enters the mixing chamber **110**. The mixing chamber **110** can then be emptied and cleaned, as described below.

Recall that the soil analysis device **100** performs field-moist analysis on a soil sample solution. In order to increase the accuracy of the analysis, it is helpful to clean the equipment (e.g., the mixing chamber **110**, filtration system **140**, and/or measurement cell **150**) between soil samples. To make this process easier, the soil analysis device **100** can be configured to self-clean between soil samples. Once the soil analysis device has been cleaned, the next soil sample can be loaded and analyzed.

In one embodiment, the soil analysis device **100** cleans itself as follows: The drain box **116** opens, thereby releasing the contents of the mixing chamber **110** (e.g., the remains of a previous soil sample solution) into the drain line **117** and substantially emptying the mixing chamber **110**. The drain box **116** then closes. Cleaning fluid (e.g., deionized water) is transferred from a reservoir **130** to the mixing chamber **110**. In one embodiment, a spray nozzle (not shown) is used to add the cleaning fluid to the mixing chamber **110**. Using a spray nozzle (e.g., a full-cone spray nozzle) helps spray clean the sidewalls of the mixing chamber **110**. The mixing assembly **112** moves the cleaning fluid within the mixing chamber **100** to rinse the chamber. The drain box **116** opens, thereby releasing the contents of the mixing chamber **110** (e.g., cleaning fluid and leftover soil sample solution) into the drain line **117** and substantially emptying the mixing chamber **110**. Pressurized air is transferred from the compressed air source **120** to the mixing chamber **110** (e.g., by activating the compressed air source **120** and opening the chamber air valve **121**). The pressurized air pushes any remaining contents of the mixing chamber **110** (e.g., cleaning fluid and leftover soil sample solution) through the drain box **116** and into the drain line **117**, thereby drying the mixing chamber **110**. The drain box **116** then closes. The mixing chamber **110** is now ready to receive a new soil sample.

FIG. **3** is a three-dimensional external view of the mixing chamber **110** shown in FIG. **1**, according to one embodiment. Various elements of FIG. **3** correspond to various elements of FIG. **2**, as follows: "CHAMBER LID" corresponds to chamber lid **111**. "SOIL PROCESSING CHAMBER" corresponds to mixing chamber **110**. "DRAIN BOX" corresponds to drain box **116**. "MOTOR BOX" corresponds to mixing assembly **112**.

FIG. **4** is a cross-sectional view of the mixing chamber **110** shown in FIG. **1**, according to one embodiment. Various elements of FIG. **4** correspond to various elements of FIG. **2**, as follows: "CHAMBER LID" corresponds to chamber lid **111**. "SOIL PROCESSING CHAMBER" corresponds to mixing chamber **110**. "DRAIN BOX" corresponds to drain box **116**. "MOTOR BOX", "MOTOR", "IMPELLER", and "BEARING ASSEMBLY" correspond to mixing assembly **112**. "WASTE OUTLET" corresponds to waste outlet **118**.

FIG. **5** is a block diagram of a measurement cell **150** for analyzing a soil sample solution, according to one embodiment. The measurement cell **150** is configured to optically measure characteristics of the soil sample solution received from the filtration system **140**. The measurement cell **150** includes or is coupled to an input port **153** for receiving the soil sample solution, a cavity **154**, one or more windows **155**, **156**, an optical source **152**, one or more optical detectors **151*a***, **151*b***, and an output port **157**.

The optical source **152** initiates the measurement of the characteristics of the soil sample solution by passing light through the soil sample solution. A detector **151*a*** is placed opposite from the optical source **152** across the cavity **154**, to capture an attenuation spectrum of the light passing through the soil sample solution as a function of wavelength. In one embodiment, detectors **151** are spectrometers having a 1 to 4 nanometer resolution. The detectors **151** have a sufficient sensitivity to allow detection of light passing through materials having a high absorbance. This allows the detectors **151** to determine an attenuation spectrum associated with a soil sample solution by determining how different wavelengths of light are attenuated by the soil sample solution present in the cavity **154**.

In one embodiment, a second detector **151***b* is placed on the same side of the cavity **154** as the light source **152**, in order to obtain a reflection spectrum of the light reflected from the soil sample solution. The reflection spectrum may be used to determine characteristics of the soil sample.

Peaks in the attenuation spectrum allow identification of components of the soil. For example, attenuation peaks at wavelengths of approximately 200 nanometers and 300 nanometers indicate nitrate-nitrogen in the soil. Similarly, attenuation peaks at wavelengths of approximately 210 nanometers, 230 nanometers and 250-300 nanometers may be used to identify nitrite-nitrogen, bisulfide and organic carbon, respectively, in the soil. Other peaks in the attenuation spectrum may also be used to identify additional components of the soil. Additionally, if the soil sample solution contains chemicals in addition to soil and extractant, additional attributes of the soil in a sample may be determined from the effect of the chemicals on the attenuation spectrum. For example, if the soil sample solution includes a pH indicator, data captured by the detector **151***a* may be used to monitor the pH indicator and ascertain soil pH. As another example, the soil sample solution may include acids and/or reagents to enable the detector **151***a* to measure the amount of phosphorous or potassium in the soil.

In one embodiment, the light source **152** comprises a dual ultraviolet-visible/near-infrared light bulb, such as a dual tungsten-deuterium bulb. The light source **152** allows independent control of the production of ultraviolet light, visible light and near-infrared light. For example, modification of a tungsten filament in the light source **152** modifies production of light having wavelengths of 320 nanometers or longer ("visible light" and "near-infrared light"), while modification of a deuterium filament in the light source **152** modifies production of light having wavelengths shorter than 400 nanometers ("ultraviolet light" or "UV light").

The light source **152** may include a light source holder (not shown) connected to the window **156**, where the light source holder includes an opening enabling the coupling of light (either by an optical fiber or by free-space optics) to the window **156**. For example, an optical fiber inserted into the opening in the light source holder directs light from the light source **152** through the optical fiber to the window **156**.

Light emitted from the light source **152** travels an optical path length from the window **156** covering light source **152** to the window **155** covering detector **151***a*. The optical path length affects the amount of light captured by a detector **151**. Thus, modifying the distance between window **156** and window **155** affects the amount of visible or ultraviolet light absorbed by the soil sample solution in the measurement cell. In one embodiment, the optical path length between windows **156** and **155** is one millimeter.

Windows **156** and **155** isolate the source **152** and detectors **151** from the soil sample solution present in the cavity **154**. Windows **156** and **155** have a high transmission of infrared, ultraviolet and visible light. For example, windows **156** and **155** may include quartz or fused-silica windows. In one embodiment, the windows **156** and **155** include a hydrophilic film, such as a film of silicon dioxide, to reduce the likelihood of air bubbles developing near the windows. Alternatively the windows **156** and **155** are made from a hydrophilic material. In one embodiment, the windows **156** and **155** include a non-stick coating such as a TEFLON coating.

Filtration of the soil sample solution by the filtration system **140** slows down the rate at which soil sample solution arrives at the measurement cell **150** for measurement. In some cases, filtration may cause one drop at a time to pass through the filtration system **140** and enter cavity **154**, which depending upon the cavity **154** may cause surface effects on windows **156** and **155**. Surface effects include, for example, splashing or the formation of bubbles.

In one embodiment, cavity **154** is sloped in order to prevent the occurrence of surface effects on windows **156** and **155**. The cavity **154** may, for example, be slanted (e.g., angled) or curved. The slope mitigates the kinetic energy of the soil sample solution that has been filtered by the filtration system **140**, thereby inhibiting the creation of surface effects on windows **156** and **155**. As a consequence, windows **156** and **155** are more likely to be uniformly covered by a soil sample solution. This improves the optical measurement of soil characteristics, by creating a more consistent optical path for light that is transmitted or reflected by the soil sample solution.

The measurement cell **150** additionally includes an output port **157** for clearing the contents of the measurement cell **150**. The output port **157** may additionally be used to input cleaning fluid to provide backpressure to clean the measurement cell **150** and/or the filtration system **140**. To perform cleaning, the output port **157** may be coupled to a standard solenoid valve that opens and closes to allow fluid and air to flow through.

In one embodiment, the soil analysis device **100** may include a number of measurement cells **150** allowing the measurement of different characteristics of the soil sample simultaneously. For example, a second measurement cell may be used to measure soil pH concurrently with the measurement of other soil nutrients.

In addition to measurements performed by the measurement cell **150**, the soil analysis device **100** may also include additional measurement devices **113** in mixing chamber **110** for performing further measurements of the soil sample. Examples of measurement devices **113** include a conductivity probe, a glass pH electrode, and ion selective electrodes including membranes for measuring various nutrients such as nitrate and potassium. The additional measurement devices **113** may also determine a moisture content of a soil sample, a viscosity of the soil sample or the soil sample solution, the temperature of the soil sample or the soil sample solution, or any other suitable characteristics of the soil sample or the soil sample solution. The data determined by the additional measurement devices **113** may be combined with the attenuation spectrum determined by the detector **151** to increase the accuracy of nutrient identification in the soil sample. For example, determining the moisture content of the soil sample allows improvement of a nitrate-nitrogen measurement by subtracting the weight of moisture in the soil sample from the weight of the soil sample. In one embodiment, an additional measurement device **113** captures optical reflectivity measurements of the soil in the mixing chamber **110**, before extractant mixing, in the UV, visible, near IR and/or mid IR spectra. The reflectivity of dry soil as a function of wavelength may be correlated to soil type. Such information can be used, in conjunction with the other embodiments discussed herein to provide data about soil characteristics or to refine the measurement of soil characteristics in the measurement cell **150**.

The soil analysis device **100** allows for near real-time analysis of soil components by integrating mixing of a soil sample and extractant with analysis of the resulting soil sample solution. For example, the soil measurement of interest is often a final value after all relevant nutrients in the soil have been extracted from the soil sample solution, which may take a significant amount of time. By integrating a high-speed measurement (typically less than 1 second per measurement)

measurement cell **150** and coupling it to the mixing chamber **110**, the measurement can be performed by the measurement cell **150** many times as the nutrient is being extracted and as the soil sample solution filters through the filtration system **140**, allowing the final value of the nutrient to be accurately extrapolated in a much shorter amount of time. In contrast, conventional techniques of soil measurement are time-intensive because they rely on discrete steps of pre-processing the soil, extracting nutrients and then measuring nutrients, preventing these conventional methods from obtaining multiple measurements of soil characteristics during the measurement process.

The flow through rate of the filtration system **140** may be slow enough that air bubbles may occasionally become trapped in between drops of soil sample solution arriving in the measurement cell **150** from the filtration system **140**. The air bubbles cause the filtering soil sample solution to become backed up, and can alter measurements of the soil sample solution. To prevent this, in one embodiment the soil analysis includes an overflow line (not shown) before the cavity **154**. The overflow line allows trapped air bubbles to escape, allowing filtered soil sample solution to take their place instead. The overflow line is positioned proximately to the filtration system **140** above, vertically, the measurement cell **150** to allow the air to escape.

The overflow line also provides a place where filtered soil sample solution may go once the measurement cell **150** has filled with filtered soil sample solution. The overflow line thus removes excess filtered soil sample solution that is not needed for measurement.

In an alternative embodiment, the shape of the measurement cell **150** may be modified into a "V" shape by adding an upward sloping overflow line at the bottom point of the cavity **154**. In this embodiment, the overflow line slopes in a different direction than the input to cavity **154**, forming the V-shape. The second portion of the V-shape is formed by the overflow line, allowing trapped air bubbles and excess filtered soil sample solution to escape from the measurement cell **150**. In this embodiment, the other elements of the measurement cell **150** such as the light source **152**, detector(s) **151**, and windows **156** and **155** may be located out-of-plane from the V-shape. The output port **157** may be located at the bottom of the V-shape next to cavity **154**.

FIG. **6** is a high-level block diagram illustrating a system **600** for controlling a soil analysis device configured to create a soil sample solution, according to one embodiment. For example, the system **600** controls operation of the soil analysis device **100**. As shown, the system **600** includes a network **610**, a repository **620**, and a processing server **630**. The repository **620** stores data that can be used in controlling operation of the soil analysis device **100**. The processing server **630** stores computer program modules (e.g., executable computer program instructions and/or other logic) that can be used in controlling operation of the soil analysis device **100**. While only one of each entity is shown in the embodiment depicted in FIG. **6** for clarity, other embodiments can have multiple repositories **620** and/or processing servers **630**.

The network **610** represents the communication pathway between the repository **620** and the processing server **630**. In one embodiment, the network **610** uses standard communications technologies and/or protocols and can include the Internet. Thus, the network **610** can include links using technologies such as Ethernet, 802.11, worldwide interoperability for microwave access (WiMAX), 2G/3G/4G mobile communications protocols, digital subscriber line (DSL), asynchronous transfer mode (ATM), InfiniBand, PCI Express Advanced Switching, etc. Similarly, the networking protocols used on the network **610** can include multiprotocol label switching (MPLS), transmission control protocol/Internet protocol (TCP/IP), User Datagram Protocol (UDP), hypertext transport protocol (HTTP), simple mail transfer protocol (SMTP), file transfer protocol (FTP), etc. The data exchanged over the network **610** can be represented using technologies and/or formats including image data in binary form (e.g. Portable Network Graphics (PNG)), hypertext markup language (HTML), extensible markup language (XML), etc. In addition, all or some of the links can be encrypted using conventional encryption technologies such as secure sockets layer (SSL), transport layer security (TLS), virtual private networks (VPNs), Internet Protocol security (IPsec), etc. In another embodiment, the entities on the network **610** can use custom and/or dedicated data communications technologies instead of, or in addition to, the ones described above.

The repository **620** is a computer (or set of computers) that stores a desired soil-to-extractant ratio **622** and soil sample data **624**. In one embodiment, the repository **620** includes a server that provides the processing server **630** read and write access to the desired soil-to-extractant ratio **622** and soil sample data **624** in response to requests.

The desired soil-to-extractant ratio **622** is a ratio representing the amount of soil versus moisture in a soil sample solution. Recall that a soil sample solution is prepared by combining a raw soil sample and an extractant (e.g., deionized water). Field-moist analysis is then performed on the solution. It is sometimes desirable to create a soil sample solution with a particular ratio of soil and moisture (e.g., 1:1, 1:2, 1:3, or 1:10). The soil-to-extractant ratio in this desired soil sample solution is stored as the desired soil-to-extractant ratio **622**. In one embodiment, the desired soil-to-extractant ratio **622** contains a default value that can be overridden by a provided value (e.g., a value provided by a user or by a file). In another embodiment (not shown), the repository **620** stores multiple soil-to-extractant ratios (e.g., so that the ratios can be provided to a user to choose from), and one of these ratios is indicated (e.g., flagged) as the desired soil-to-extractant ratio **622**.

Soil sample data **624** includes information regarding the mass and the moisture content of one or more raw soil samples. Each raw soil sample has a particular mass and a particular moisture content and is assigned a unique identifier. The soil sample data **624** associates this unique identifier with information regarding the mass and the moisture content of the identified raw soil sample. In one embodiment, the soil sample data **624** is stored in a database.

In one embodiment, the unique identifier is a single value assigned to only one sample. In another embodiment, the unique identifier is a pair of values, where one value indicates a particular batch of different samples and another value indicates the sample's position within that batch. The unique identifier can be partially or fully encoded in a machine-readable form such as a barcode or a radio frequency identifier (RFID) tag. This machine-readable form can then be affixed to the sample container.

Note that storing a soil sample's mass information and moisture information electronically as soil sample data **624** is optional. In a different embodiment, a soil sample's mass information and moisture information are affixed to the sample's container (e.g., by manually writing the information on the container) instead of being stored electronically as soil sample data **624**. In that embodiment, the soil sample's mass information and moisture information are received via user input (e.g., by a user entering them using an input device (not shown)) so that they can be used by the soil solution preparation module **638** (described below).

The processing server **630** includes various modules such as an extractant calculation module **632** for calculating a needed amount of extractant, a reservoir dispensing module **634** for dispensing a particular amount of extractant and/or cleaning fluid, a mixing module **636** for mixing the contents of the mixing chamber **110**, a soil solution preparation module **638** for preparing a soil sample solution with a particular soil-to-extractant ratio, and a cleaning module **639** for cleaning the mixing chamber **110**. In one embodiment, the processing server **630** includes a computer (or set of computers) that communicates with repository **620**, processes data (e.g., by executing the extraction calculation module **632**), and controls the soil analysis device **100** (e.g., by executing the reservoir dispensing module **634**, the mixing module **636**, the soil solution preparation module **638**, and the cleaning module **639**).

The extractant calculation module **632** calculates a needed amount of extractant. In particular, the extractant calculation module **632** determines how much extractant should be added to a particular raw soil sample to generate a soil sample solution with a particular soil-to-extractant ratio. In one embodiment, the extractant calculation module **632** calculates the needed amount of extractant as follows:

$$M_{dg}=M_{fm}*(100-P_{moisture})/100$$

$$M_{water}=M_{fm}*P_{moisture}/100$$

$$M_{extractant}=(R*M_{dg})-M_{water}=(R*M_{fm}*(100-P_{moisture})/100)-(M_{fm}*P_{moisture}/100)$$

$$V_{extractant}=M_{extractant}/D_{extractant}$$

where $M_{extractant}$ represents the mass of extractant needed, $V_{extractant}$ represents the volume of extractant needed, $D_{extractant}$ represents the density of the extractant (for deionized water, $D_{extractant}$=1 g/mL), M_{fm} represents the mass of a field-moist soil sample, $P_{moisture}$ represents the percentage of moisture of a field-moist soil sample, M_{water} represents the mass of water of a field-moist soil sample, M_{dg} represents the dry equivalent mass of a soil sample, and R represents the desired extractant-to-soil ratio (e.g., R=10 means 10:1 extractant-to-soil ratio).

The reservoir dispensing module **634** dispenses a particular amount of extractant and/or cleaning fluid. In particular, the reservoir dispensing module **634** causes a particular amount of extractant and/or cleaning fluid to be moved from the reservoir **130** to the mixing chamber **110**. In one embodiment, extractant is moved, and the particular amount of extractant to be moved is equal to the needed amount of extractant calculated by the extractant calculation module **632** to generate a soil sample solution with a particular soil-to-extractant ratio. In another embodiment, cleaning fluid is moved, and the particular amount of cleaning fluid to be moved is equal to the amount of cleaning fluid needed to clean the mixing chamber **110**.

Causing a particular amount of extractant and/or cleaning fluid to be moved from the reservoir **130** to the mixing chamber **110** is performed by sending commands to the reservoir air valve **131**, the reservoir fill valve **133**, the chamber air valve **121**, and the compressed air source to begin moving extractant and/or cleaning fluid from the reservoir **130** to the mixing chamber **110** (explained above with reference to FIG. **2**). The extractant and/or cleaning fluid flows through the flow meter **134**, which measures the flow of the extractant and/or cleaning fluid. The amount of the measured flow is sent from the flow meter **134** to the reservoir dispensing module **634** so that the reservoir dispensing module **634** can determine how much extractant and/or cleaning fluid is being added to the mixing chamber **110**. After the proper amount of extractant and/or cleaning fluid has been added to the mixing chamber **110** (as indicated by the flow meter **134**), the reservoir dispensing module **634** sends commands to the reservoir air valve **131**, the reservoir fill valve **133**, the chamber air valve **121**, and the compressed air source to cease moving extractant and/or cleaning fluid from the reservoir **130** to the mixing chamber **110**.

The mixing module **636** mixes the contents of the mixing chamber **110**. In particular, the mixing module **636** sends a command to the mixing assembly **112** to activate the mixing assembly **112**, thereby mixing the contents of the mixing chamber **110**. In one embodiment, the command causes the mixing assembly **112** to be activated for a predetermined length of time. In another embodiment, the command causes the mixing assembly **112** to remain activated until the mixing assembly **112** receives another command from the mixing module **636**, causing the mixing assembly **112** to stop being activated.

The soil solution preparation module **638** prepares, from a particular soil sample, a soil sample solution with a particular soil-to-extractant ratio. In particular, the soil solution preparation module **638** prepares a soil sample solution with the soil-to-extractant ratio indicated in the desired soil-to-extractant ratio **622**. Execution of the soil solution preparation module **638** proceeds automatically (i.e., without user intervention) and enables the mixing chamber **110** to be self-filling. In one embodiment, the soil solution preparation module **638** operates as follows:

1. The soil solution preparation module **638** determines the previously-measured mass and moisture content of the particular soil sample. If the mass and moisture content are stored as soil sample data **624**, then they are obtained using the particular soil sample's unique identifier. If the mass and moisture content are stored manually (e.g., affixed to the sample container), then they were previously received via user input (e.g., by a user entering them using an input device (not shown)).

2. The soil solution preparation module **638** obtains the desired soil-to-extractant ratio **622**. The desired soil-to-extractant ratio **622** can be a default value or a previously-received value (e.g., from user input or a file).

3. The soil solution preparation module **638** executes the extractant calculation module **632** to determine how much extractant is needed to prepare, from this particular soil sample, a soil sample solution with the desired soil-to-extractant ratio **622**.

4. The soil solution preparation module **638** executes the reservoir dispensing module **634** to dispense a particular amount of extractant (specifically, the amount determined in the previous step) from the reservoir **130** to the mixing chamber **110**.

5. The soil solution preparation module **638** executes the mixing module **636** to mix the contents of the mixing chamber **110** (e.g., a raw soil sample and the extractant added in the previous step). The result is a soil sample solution with the desired soil-to-extractant ratio.

The cleaning module **639** cleans the mixing chamber **110**. In particular, the cleaning module **639** causes the mixing chamber to be drained of its contents, causes cleaning fluid to be moved from the reservoir **130** to the mixing chamber **110**, causes the mixing chamber to be rinsed with the cleaning fluid, and causes the mixing chamber to be dried. Causing these steps to occur is performed by sending commands to the drain box **116**, the chamber air valve **121**, and the compressed air source **120** (explained above with reference to FIG. **2**) and executing the reservoir dispensing module **634** and the mixing module **636**. Execution of the cleaning module **639** proceeds automatically (i.e., without user intervention) and enables the mixing chamber **110** to be self-cleaning.

FIG. **7** is a high-level block diagram illustrating an example of a computer **200** for use as a repository and/or a processing server, according to one embodiment. Illustrated are at least one processor **202** coupled to a chipset **204**. The chipset **204** includes a memory controller hub **250** and an input/output (I/O) controller hub **255**. A memory **206** and a graphics adapter **213** are coupled to the memory controller hub **250**, and a display device **218** is coupled to the graphics adapter **213**. A storage device **208**, keyboard **210**, pointing device **214**, and network adapter **216** are coupled to the I/O controller hub **255**. A code scanner (e.g., a barcode scanner or RFID scanner, not shown) can also be coupled to the I/O controller hub **255**. Other embodiments of the computer **200** have different architectures. For example, the memory **206** is directly coupled to the processor **202** in some embodiments.

The storage device **208** includes one or more non-transitory computer-readable storage media such as a hard drive, compact disk read-only memory (CD-ROM), DVD, or a solid-state memory device. The memory **206** holds instructions and data used by the processor **202**. The pointing device **214** is used in combination with the keyboard **210** to input data into the computer system **200**. The code scanner (not shown) is used to input data into the computer system **200**. The graphics adapter **213** displays images and other information on the display device **218**. In some embodiments, the display device **218** includes a touch screen capability for receiving user input and selections. The network adapter **216** couples the computer system **200** to the network **610**. Some embodiments of the computer **200** have different and/or other components than those shown in FIG. **7**. For example, the repository **620** and/or the processing server **630** can be formed of multiple blade servers and lack a display device, keyboard, and other components.

The computer **200** is adapted to execute computer program modules for providing functionality described herein. As used herein, the term "module" refers to computer program instructions and/or other logic used to provide the specified functionality. Thus, a module can be implemented in hardware, firmware, and/or software. In one embodiment, program modules formed of executable computer program instructions are stored on the storage device **208**, loaded into the memory **206**, and executed by the processor **202**.

Measurement of Soil Characteristics

Before a raw field-moist soil sample is analyzed using the soil analysis device **100**, a subsample with known mass and moisture content is prepared. In one embodiment, the subsample is prepared as follows:

1. The raw field-moist soil sample is assigned a unique identifier.

2. The sample is prepared for subsampling by breaking up the cores and larger chunks of dirt so that a subsample of soil can provide representative results of the whole sample. The soil sample can be broken up by hand or automatically (e.g., with a food processor or similar style mixer).

3. A first subsample of soil is taken and placed into a uniquely identified container or batch of containers with a known position. The mass of the subsample is measured by weighing the subsample (either manually or automatically). The mass measurement is stored electronically (in association with the sample's unique identifier) or manually (e.g., by affixing it to the sample container or by manually writing the mass on the container). Determining the mass of a raw soil sample before mixing enables more accurate determination of the concentration of soil nutrients measured by the soil analysis device **100**.

4. A second subsample of soil is taken and used to analyze the moisture content of the soil. The moisture content is determined by first weighing the subsample, then drying the subsample (such as with a conventional oven or microwave oven), and then weighing the subsample again. The moisture measurement is stored electronically (in association with the sample's unique identifier) or manually (e.g., by affixing it to the sample container or by manually writing the mass on the container).

FIG. **8** is a flow chart of one embodiment of a method **300** for measuring data describing soil composition using the soil analysis device **100**. In the embodiment shown by FIG. **8**, the mixing chamber **110** receives **310** a soil sample having a known weight and moisture content. The mixing chamber **110** also receives **320** an extractant. In one embodiment, a volume or weight of extractant is received **320** based on the weight of the soil sample to provide a particular ratio of soil to extractant. The mixing chamber **110** may also receive a salt to act as a flocculent on the soil sample.

The contents of the mixing chamber **110** are mixed to create **330** a soil sample solution. In one embodiment, steps **320** and/or **330** are performed automatically by executing the soil solution preparation module **638**. A portion of the soil sample solution flows from the mixing chamber **110** into filtration system **140**. The filtration system **140** filters **340** the soil sample solution to remove soil particulates, organic matter, and other soluble organic materials from the soil sample solution. The filtered soil sample solution enters measurement cell **150**.

Once in the measurement cell **150**, the filtered soil sample solution is analyzed **350** to determine the characteristics of the soil sample. In one embodiment, ultraviolet, visible, and/or near-infrared light are incident upon and at least partially absorbed by the soil sample solution. An attenuation spectrum is measured that provides data regarding how the soil sample solution absorbs different wavelengths of light. Peaks in the attenuation spectrum associated with the soil sample solution allow identification of nutrients, or other components, in the soil sample. A reflection spectrum may also be measured using the light reflected from the soil sample in the measurement cell **150**. After measurement, soil analysis device **100** is cleaned **360** to remove the soil sample solution from the mixing chamber **110**, filtration system **140**, and/or measurement cell **150**. In one embodiment, step **360** is performed automatically by executing the cleaning module **639**.

FIG. **9** is a flow chart of one embodiment of a method for analyzing **350** multiple characteristics of a soil sample solution to determine soil sample characteristics. In one embodiment, one or more additional measurement cells **150** are coupled to the mixing chamber **110** and measure various characteristics of a soil sample solution. In one embodiment, measurement cell **150** and one or more additional measurement devices measure various characteristics of the soil sample and the soil sample solution. In one embodiment, measurements of various characteristics of the soil sample solution are measured in a single measurement cell **150**, where the contents of the measurement cell **150** may change between measurements for a single soil sample. For example, the soil to extractant ratio may be changed through the addition of additional extractant between measurements, or additional chemicals may be added to perform additional measurements.

In one embodiment, a thermal measurement device determines **410** a temperature of a portion of the soil sample solution. A power detector determines **420** a viscosity of the soil sample solution by measuring the power consumed by the motor in mixing chamber **110** to reach a specified speed, or by measuring the speed of the motor when a fixed amount of power is applied to the motor. In one embodiment, the measurement cell **150** is used to determine **430** an absorption and/or a reflection spectrum of the soil sample solution. In one embodiment an additional measurement device or an additional measurement cell **150** in conjunction with an added chemical determines **440** the pH of the soil.

The temperature, viscosity, attenuation spectrum and pH represent characteristics of the soil. These measurements may also be analyzed to determine other characteristics of the soil that were not directly measured. For example, the temperature, viscosity, attenuation spectrum and pH may be communicated from the soil analysis device **110** to a processor or computing device (not shown) which determines **450** the nutrients present in the soil sample. The measured and determined characteristics of the soil sample are stored **460** in a memory and/or displayed to a user. In one embodiment, the measured and determined characteristics of the soil sample are stored using a computer as described with respect to FIG. **7** above.

In one embodiment, the soil analysis device **100** is used in conjunction with a process for measuring soil characteristics as described in U.S. patent application Ser. No. 13/231,701, filed on Sep. 13, 2011, the subject matter of which is incorporated herein by reference in its entirety.

Hence, the disclosed soil analysis device **100** improves the accuracy of identifying nutrients in a soil sample while also increasing the speed with which the nutrients included in a soil sample are identified.

Additional Considerations

As used herein any reference to "one embodiment" or "an embodiment" means that a particular element, feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. The appearances of the phrase "in one embodiment" in various places in the specification are not necessarily all referring to the same embodiment.

Some embodiments may be described using the expression "coupled" and "connected" along with their derivatives. It should be understood that these terms are not intended as synonyms for each other. For example, some embodiments may be described using the term "connected" to indicate that two or more elements are in direct physical or electrical contact with each other. In another example, some embodiments may be described using the term "coupled" to indicate that two or more elements are in direct physical or electrical contact. The term "coupled," however, may also mean that two or more elements are not in direct contact with each other, but yet still co-operate or interact with each other. The embodiments are not limited in this context.

As used herein, the terms "comprises," "comprising," "includes," "including," "has," "having" or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a process, method, article, or apparatus that comprises a list of elements is not necessarily limited to only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus. Further, unless expressly stated to the contrary, "or" refers to an inclusive or and not to an exclusive or. For example, a condition A or B is satisfied by any one of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present).

In addition, use of the "a" or "an" are employed to describe elements and components of the invention. This is done merely for convenience and to give a general sense of the invention. This description should be read to include one or at least one and the singular also includes the plural unless it is obvious that it is meant otherwise.

Upon reading this disclosure, those of skill in the art will appreciate still additional alternative structural and functional designs for a system and a method for automatically identifying characteristics of the composition of a soil sample through the disclosed principles herein. Thus, while particular embodiments and applications have been illustrated and described, it is to be understood that the present invention is not limited to the precise construction and components disclosed herein and that various modifications, changes and variations which will be apparent to those skilled in the art may be made in the arrangement, operation and details of the method and apparatus of the present invention disclosed herein without departing from the spirit and scope of the invention as defined in the appended claims.

The invention claimed is:

1. A soil analysis device comprising:

a reservoir configured to store an extractant;

a mixing chamber coupled to the reservoir and configured to receive extractant from the reservoir and to receive a raw soil sample;

an air source configured to move extractant from the reservoir to the mixing chamber;

one or more valves configured to control flow of the extractant from the reservoir to the mixing chamber;

a flow meter configured to measure an amount of the extractant transferred from the reservoir into the mixing chamber through the one or more valves;

and

a control system configured to:

determine an amount of extractant needed to produce, from the raw soil sample, a soil sample solution with a particular soil-to-extractant ratio; and

cause the determined amount of extractant to be transferred from the reservoir to the mixing chamber by:

sending first one or more commands that cause the air source to begin moving the extractant from the reservoir to the mixing chamber through the one or more valves,

measuring a flow of the extractant passing from the reservoir to the mixing chamber using the flow meter, and

in response to a determination that the flow meter has measured the amount of extracted needed to produce the soil sample solution, sending second one or more commands that causes the air source to cease moving the extractant through the one or more valves.

2. The device of claim **1**, wherein determining the amount of extractant needed comprises determining a mass of the raw soil sample.

3. The device of claim **2**, wherein determining the mass of the raw soil sample comprises accessing an electronic data store.

4. The device of claim **2**, wherein determining the mass of the raw soil sample comprises receiving user input.

5. The device of claim **1**, wherein determining the amount of extractant needed comprises determining a moisture content of the raw soil sample.

6. The device of claim **5**, wherein determining the moisture content of the raw soil sample comprises accessing an electronic data store.

7. The device of claim **5**, wherein determining the moisture content of the raw soil sample comprises receiving user input.

8. The device of claim **1**, wherein the particular soil-to-extractant ratio is obtained from an electronic data store.

9. The device of claim **1**, wherein the particular soil-to-extractant ratio is obtained from user input.

10. The device of claim **1**, wherein the mixing chamber is further configured to mix the extractant and the raw soil sample to produce the soil sample solution, and wherein the control system is further configured to cause the mixing chamber to mix the extractant and the raw soil sample to produce the soil sample solution.

11. The device of claim **10**, further comprising a filtration system coupled to the mixing chamber and configured to receive the soil sample solution from the mixing chamber and to filter the received soil sample solution.

12. The device of claim **11**, further comprising a measurement cell coupled to the filtration system and configured to receive the filtered soil sample solution from the filtration system and to analyze the filtered soil sample solution.

13. The device of claim **1**, wherein the mixing chamber is further configured to clean itself, and wherein the control system is further configured to cause the mixing chamber to clean itself.

14. The device of claim **1**, wherein the extractant comprises deionized water.

15. The device of claim **1**, wherein the raw soil sample comprises a field-moist soil sample.

16. The device of claim **1**, wherein, prior to sending the one or more commands, the control system is configured to clear out one or more pipes or tubes coupling the mixing chamber to the reservoir using the air source.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,291,545 B1
APPLICATION NO. : 13/797546
DATED : March 22, 2016
INVENTOR(S) : Justin S. White et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page:

The first or sole Notice should read --

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 412 days.

Signed and Sealed this
Fifteenth Day of November, 2016

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office